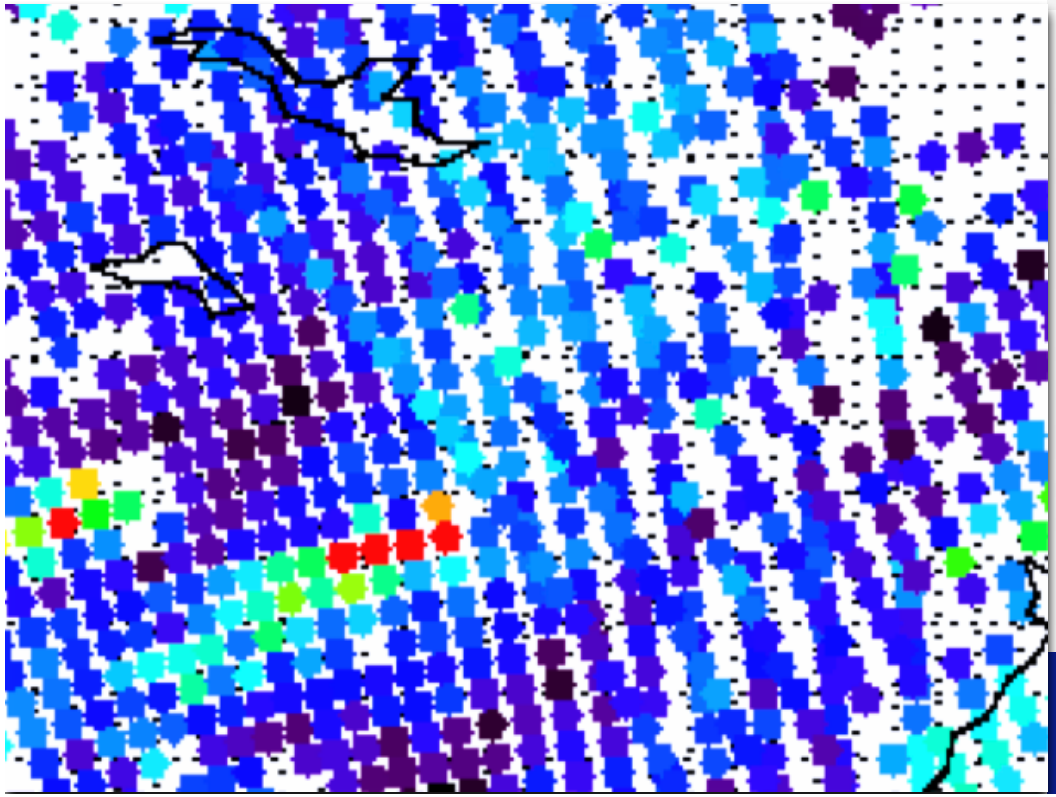
The space-time structure of NUCAPS trace gas products



Nadia Smith[1], Stuart McKeen[2], R. Bradley Pierce[3]
Greg Frost[2], Chris Barnet[1], Antonia Gambacorta[1],
Jonathan Smith[1] and Mitch Goldberg[4]

1. Science and Technology Corporation (STC)
2. NOAA/ESRL/CSD
3. NOAA/NESDIS/STAR
4. NOAA/JPSS

NASA Sounder Science Team Meeting
13-16 Sep 2016, Greenbelt, MD

Why should we spend time improving our algorithms and products?

Who are the users affected by product quality and differences?

Which science questions are being addressed with our products?

NOAA Proving Ground and Risk Reduction (PGRR)

We address product improvement and application in interagency and interdisciplinary teams

Sounder, Fire & Smoke and Trace Gas Initiatives

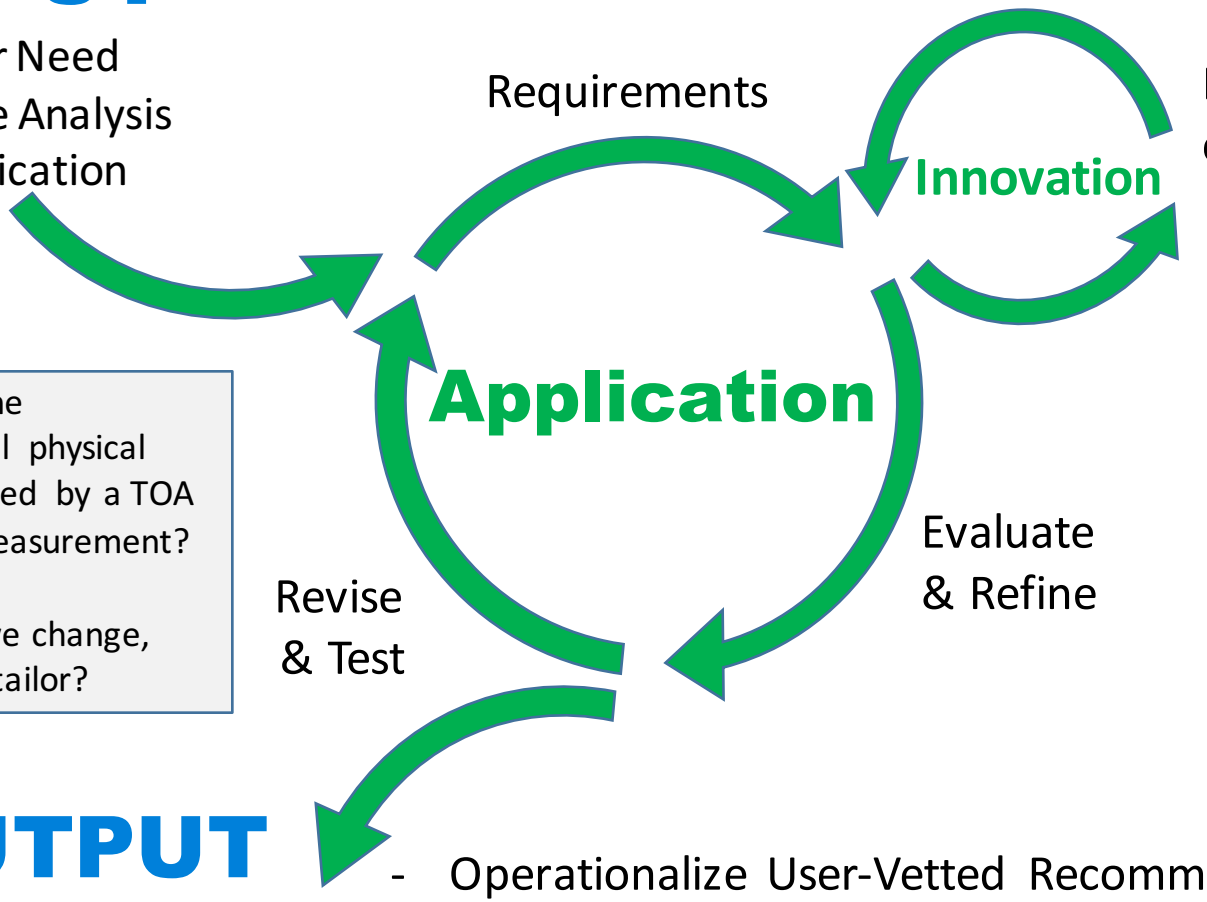
Operational products are evaluated and improved within user applications

NOAA PGRR: A User-Oriented Approach to Development

See NOAA Test Bed Concept in Ralph et al. 2013 BAMS

INPUT

User Need
Science Analysis
Application



What are the fundamental physical limits imposed by a TOA radiance measurement?

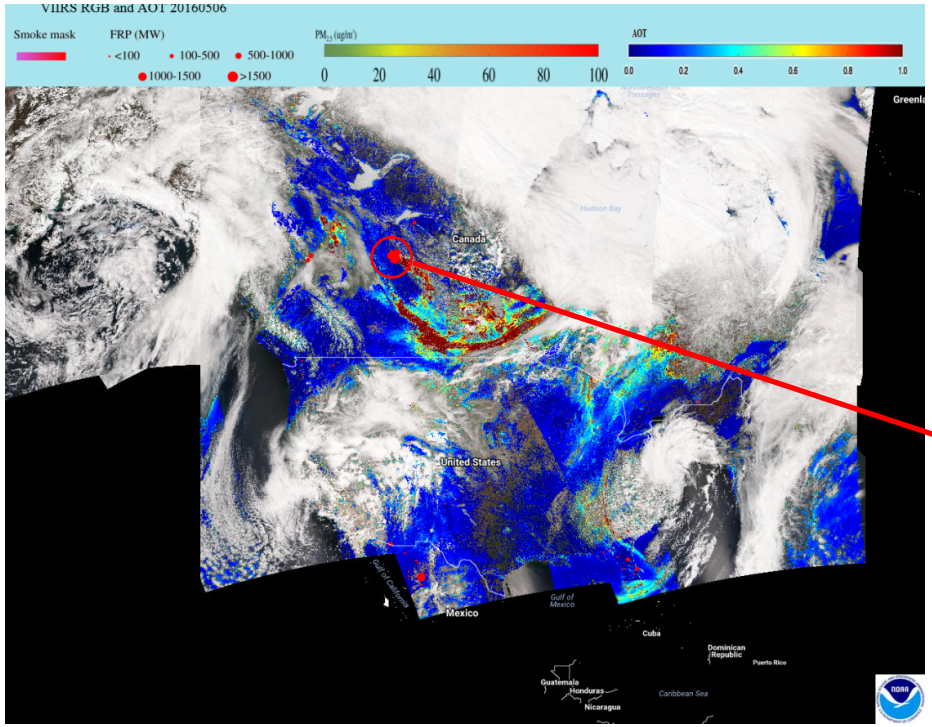
What can we change, improve & tailor?

Loops are maintained by active & collaborative **User-Developer Partnerships**

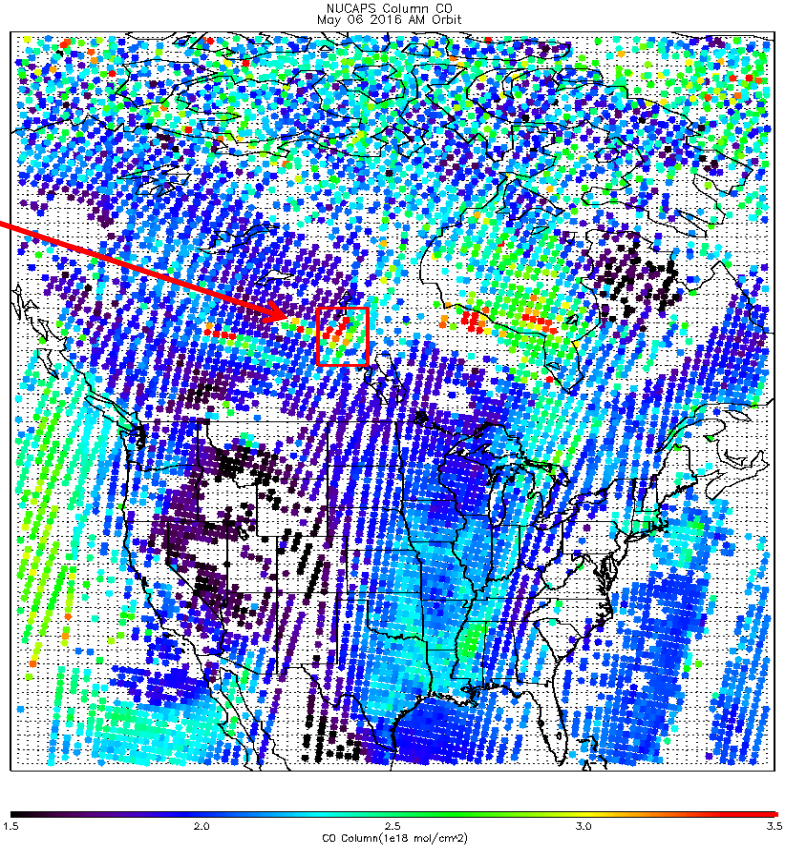
This leads to:
(1) Improved user/developer understanding
(2) Products tailored to user applications

OUTPUT

- Operationalize User-Vetted Recommendations
- Develop/Enhance Applications

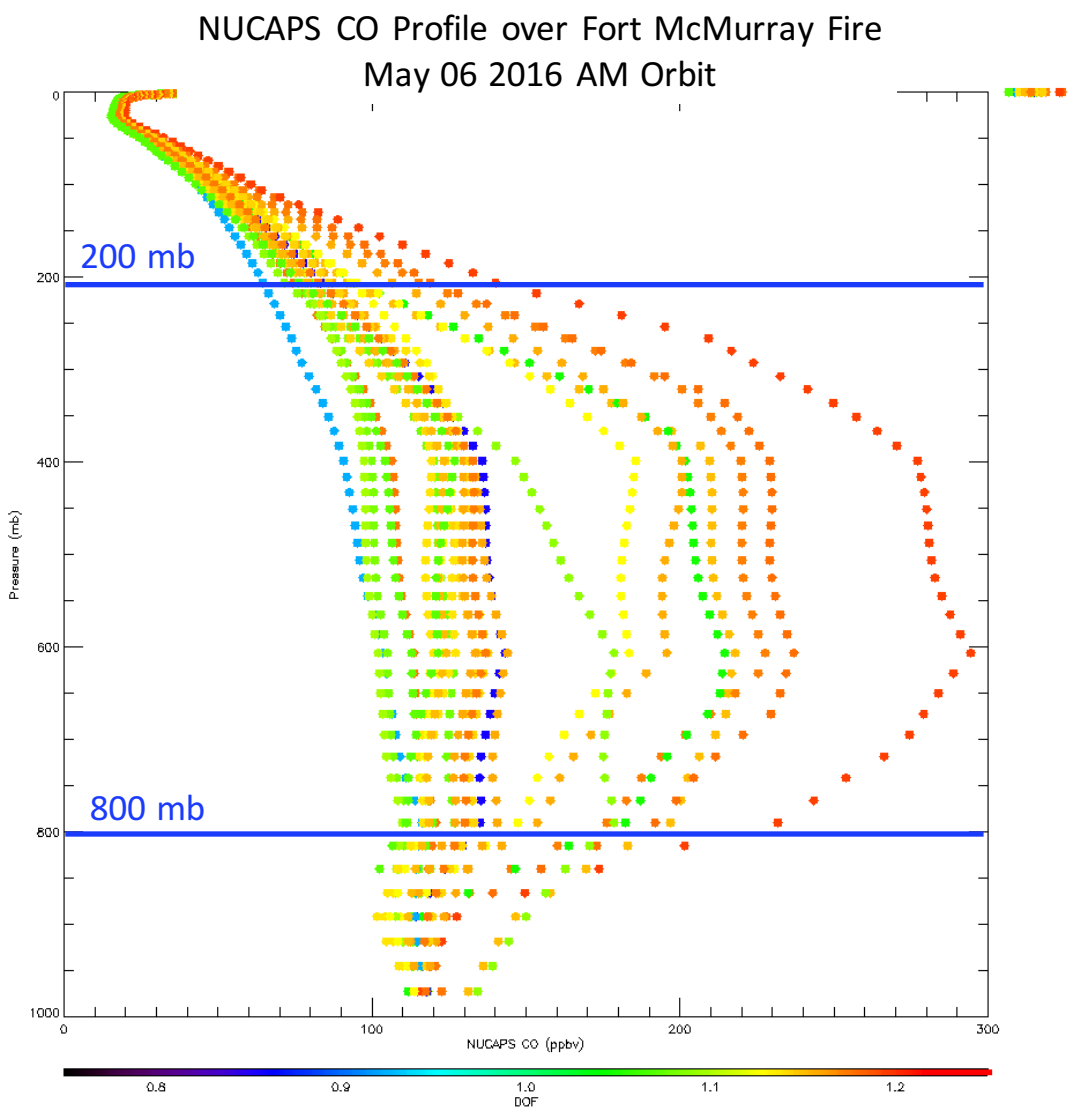


NUCAPS trace gas products: CO + CH4
Generated at AMSU footprint (~50 km) from cloud-cleared radiances – improved coverage under clear and partly-cloudy conditions



Brad Pierce (PGRR PI): High resolution trajectory-based smoke forecasts

Greg Frost (PGRR PI): Understanding emissions and tropospheric chemistry

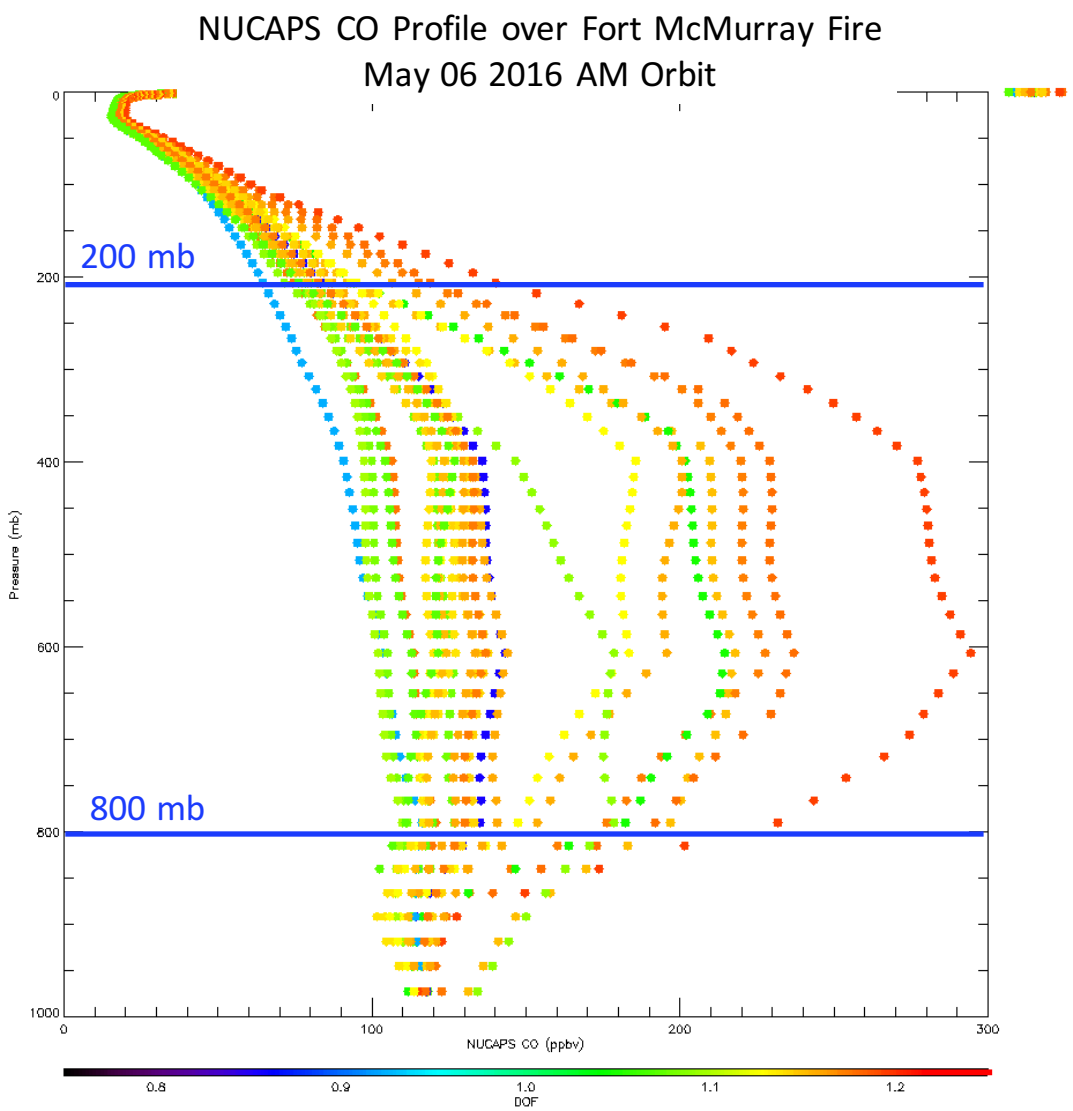


CO varies between 100 – 300 ppbv and Degrees of Freedom (DOF) varies 0.8 (blue) to 1.2 (orange).

NUCAPS CO captures meso-scale source site over regional biomass burning event.

But compared to other data sources (VIIRS, models, in situ) the spatial and vertical resolution is reduced and should be accounted for

(Brad Pierce)



Meeting User Needs for Data Products

Averaging Kernels (AKs) are not distributed as part of the NOAA operational product suite (yet)

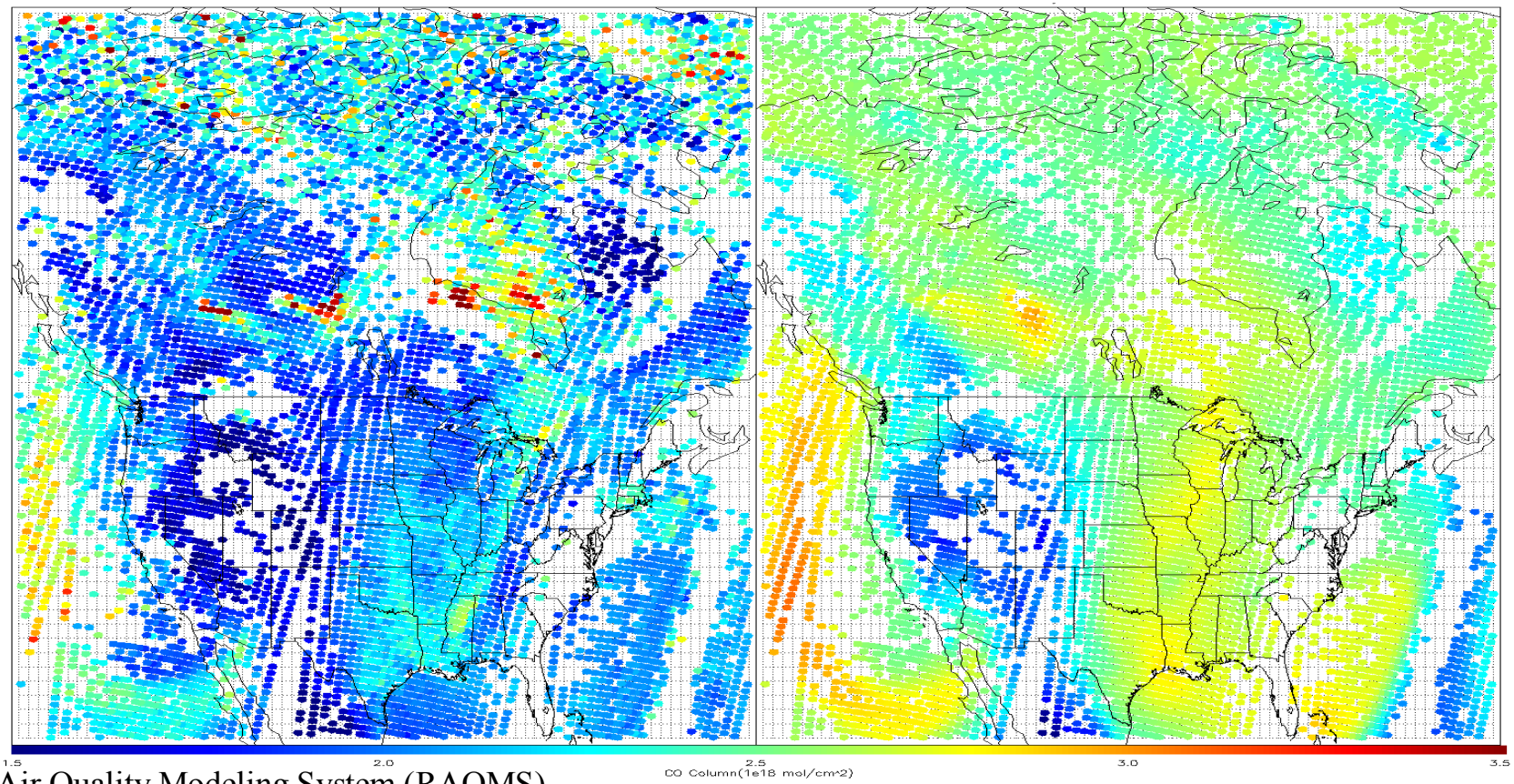
They are, however, generated by the NUCAPS system, so AKs can be distributed to users in off-line mode

Why are AKs important for trace gas product application? – to account for vertical smoothing and a-priori contribution

In collaboration with users we are working at making the distribution of AKs operational within NOAA

NUCAPS versus RAQMS
Column CO May 06, 2016 AM Orbit

NUCAPS RAQMS



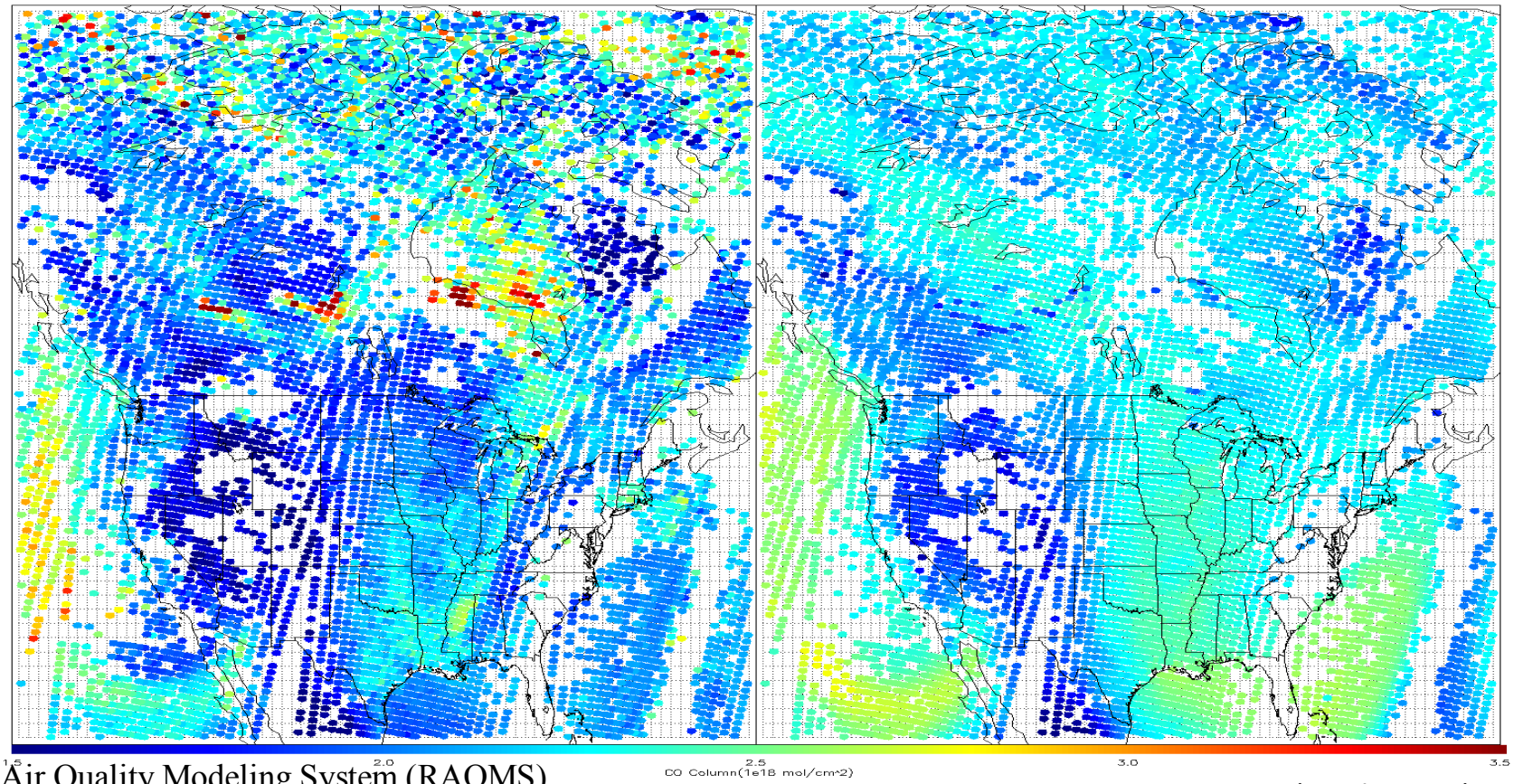
Real Time Air Quality Modeling System (RAQMS)
http://raqms-ops.ssec.wisc.edu/

(Brad Pierce)

NUCAPS versus RAQMS with Averaging Kernels applied
Column CO May 06, 2016 AM Orbit

NUCAPS

RAQMS



Real Time Air Quality Modeling System (RAQMS)
http://raqms-ops.ssec.wisc.edu/

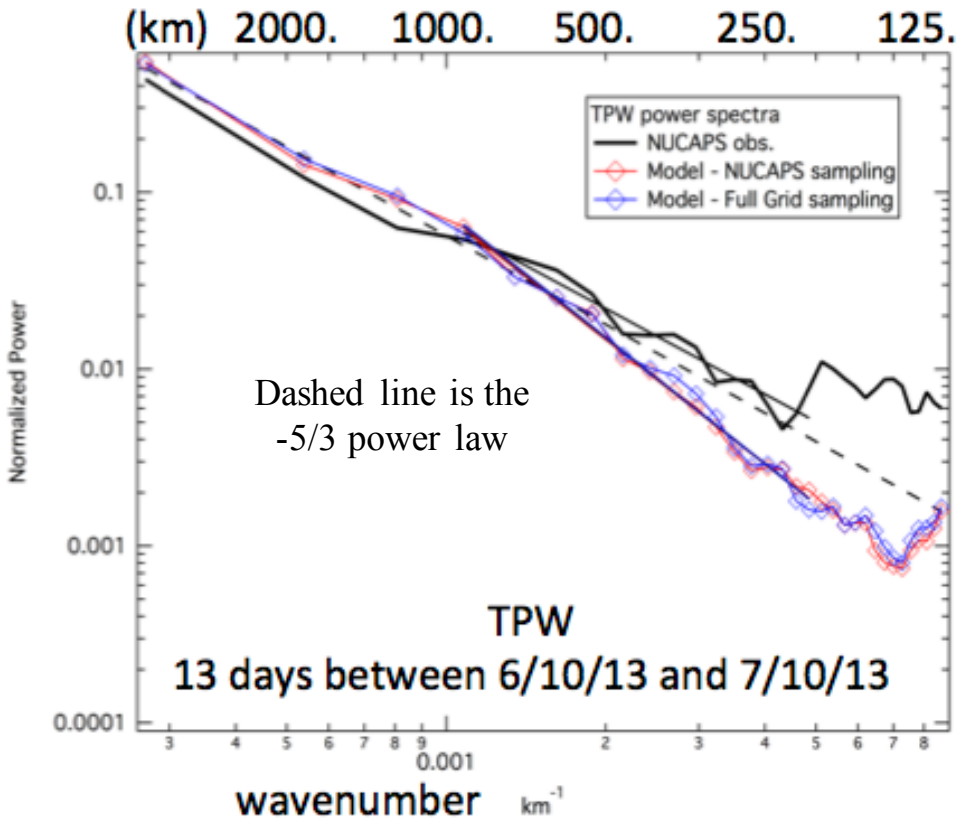
(Brad Pierce)

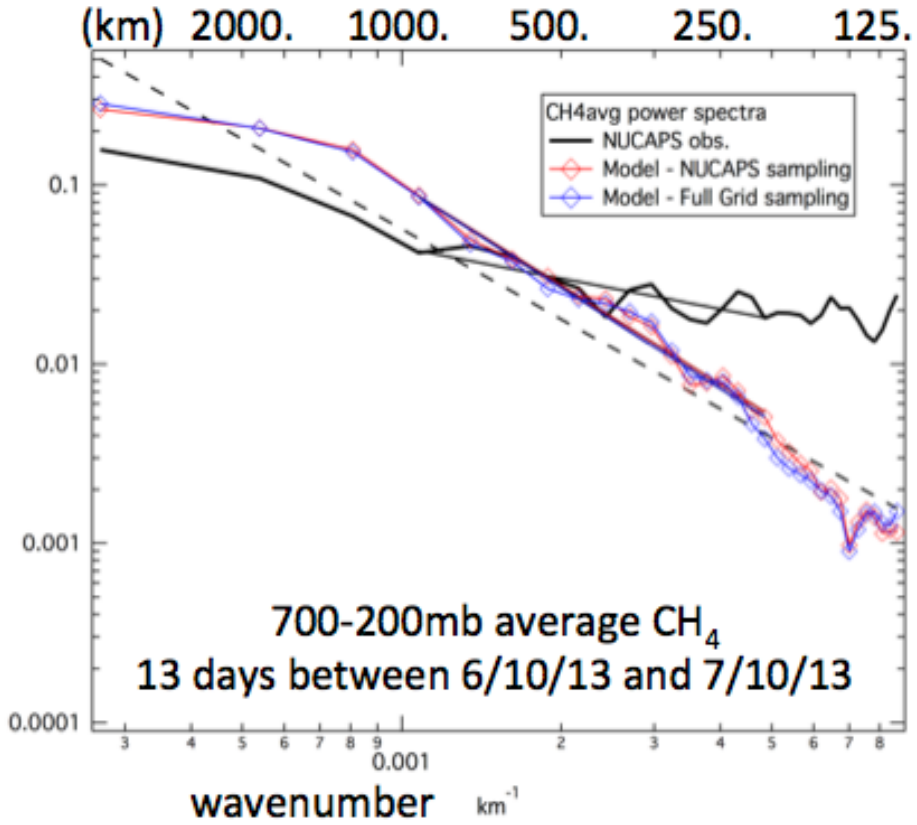
- These Auxiliary products (AK, DOF) are not yet available within the NOAA Operational product stream (distributed through CLASS)
- But they are required by user applications and specifically for data characterization
- NUCAPS creates all the building blocks with which to calculate AK and DOF and can be made available to users in an off-line mode.
- We developed a beta-version of a NUCAPS AK auxiliary product that are being tested and evaluated by users
- We will evaluate this product, fine tune its design and make recommendations for operational implementation and distribution

Evaluating atmospheric processes – Moving away from snap-shot analysis

A closer look at how variance change with scale using energy spectra

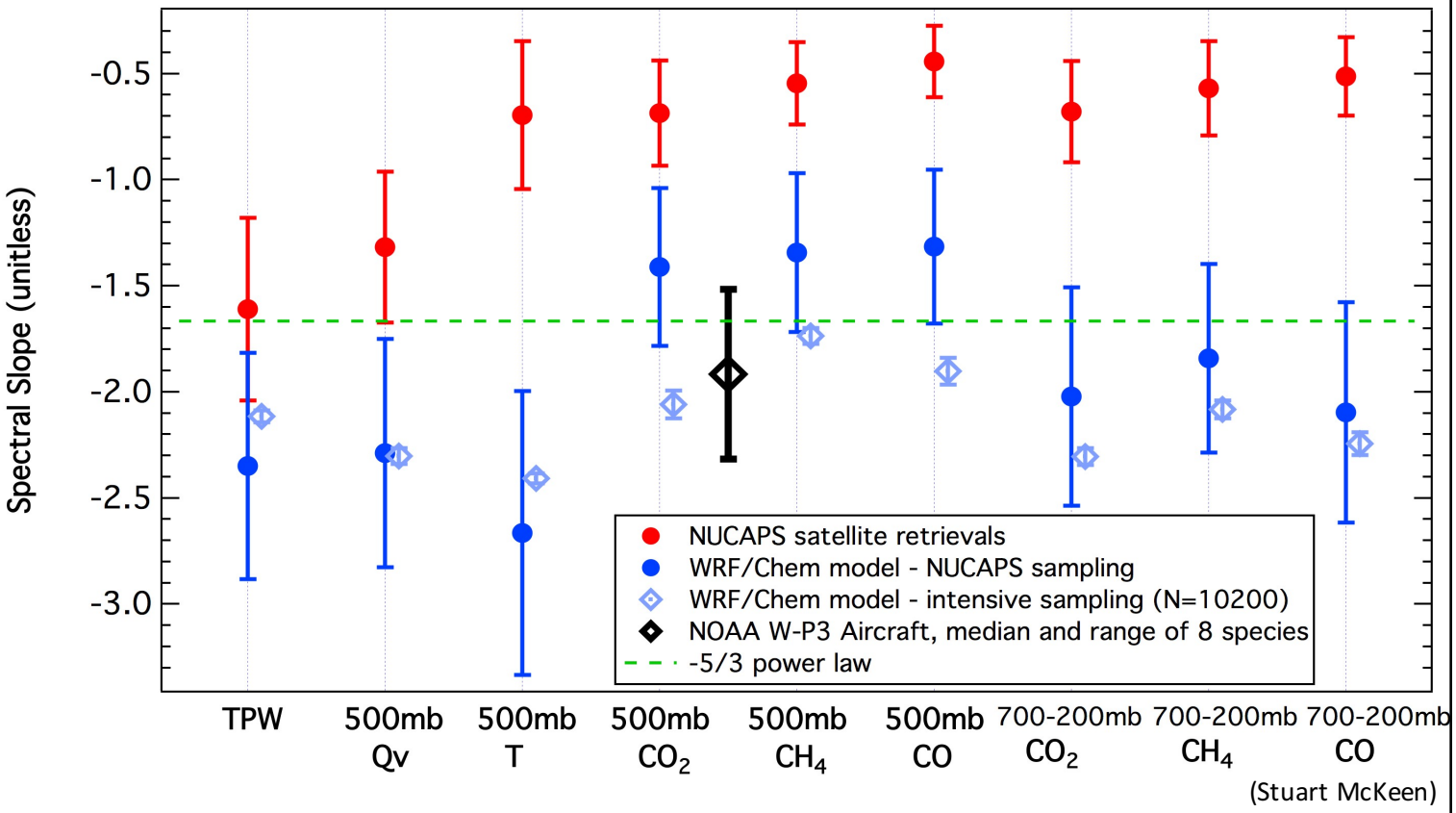
The objective is to understand how NUCAPS trace gases scale with TPW to constrain emission, chemistry and transport modeling





Analysis by Stuart McKeen

Understanding sources of NUCAPS uncertainty in applications



(1) **Spatial sampling causes systematic effects in downstream applications**

e.g. WRF/Chem at NUCAPS spatial sampling rates (~50km) produce different spectral slopes than WRF/Chem at native sampling sampling rates (~10km)

(2) NUCAPS for all parameters (except column-integrated TPW) are much lower than expected due to inclusion of all retrievals (no QC was applied) – this confirms **importance of QC,**

Spectral slopes (between 200 km and 1000 km length scale) of average normalized power spectra for vertically integrated or 500 mb values of several variables from NUCAPS and WRF-Chem. Uncertainties are the sum of the sampling uncertainty ($1/N^{1/2}$) and slope uncertainty from the regression.

Variance is a key quantity in physical processes.

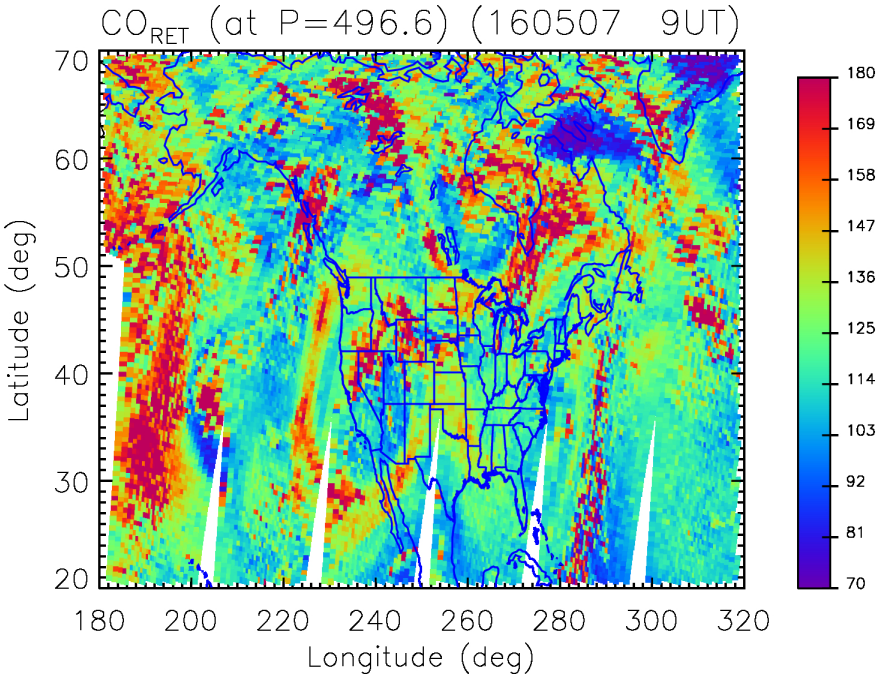
Decomposing variance in terms of contributions per scale provide insight into processes that fluctuate in space, e.g. turbulence.

Just because NUCAPS products are retrieved at a certain spatial (~50km) and vertical resolution (100 layer) does not mean those are the scales at which they should be applied – this is especially relevant to the trace gas products

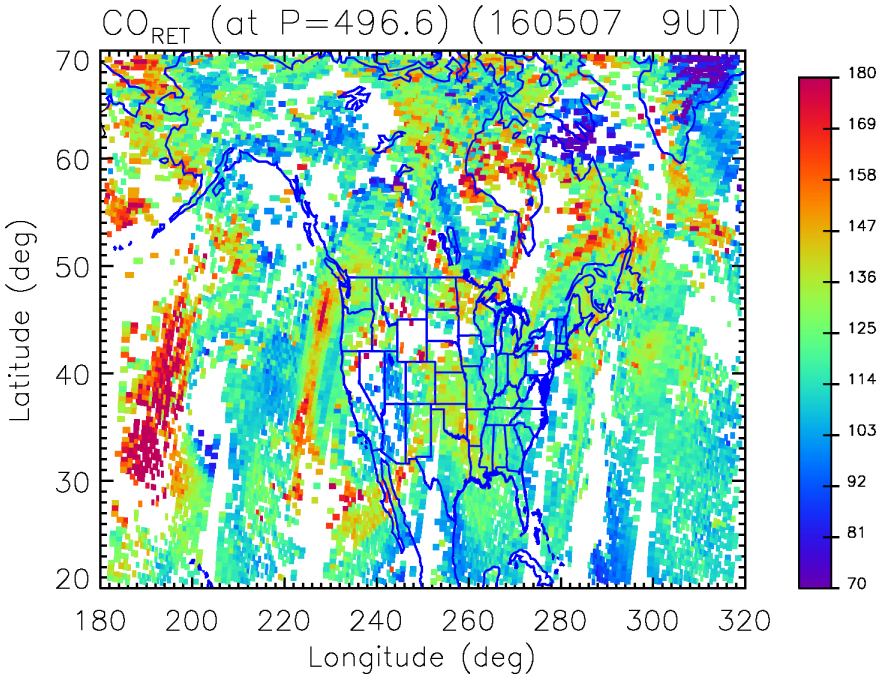
We can use variance scaling as a means with which to identify the spatial scales at which data make the most important contributions to the predicted variance, and thus identify the degree of vertical integration and spatial averaging that should be applied to products for use in applications

Quality Control – A necessary step in using Satellite Data Products

NUCAPS CO without QC



NUCAPS CO with QC



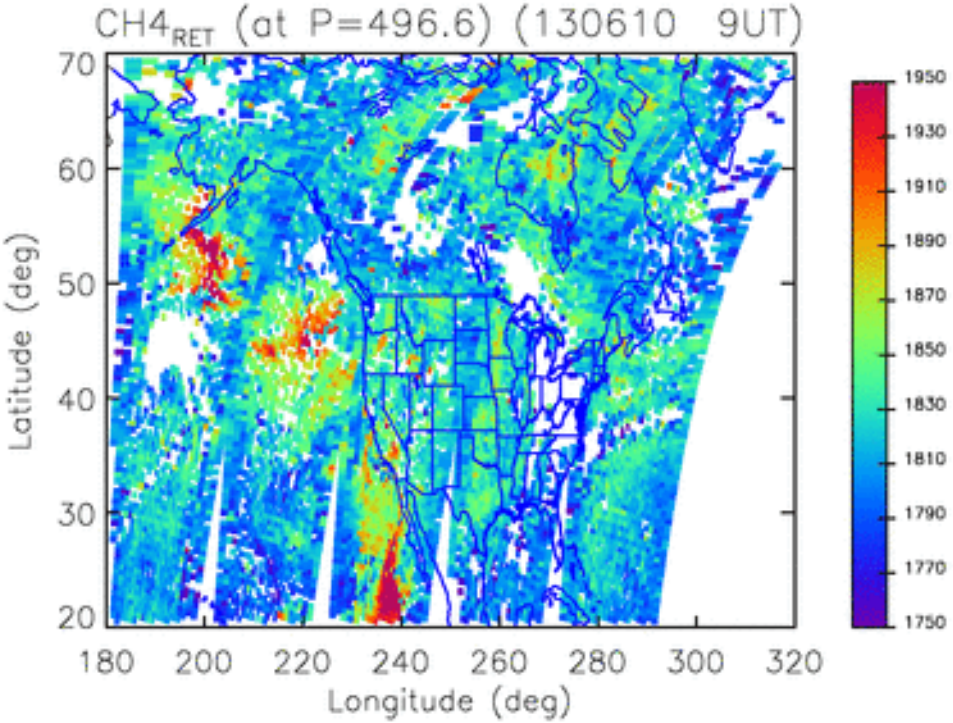
NUCAPS QC indicates quality of T/q from IR and MW retrieval steps
Designed to meet system requirements for global retrieval statistics; 1K T and 10% q

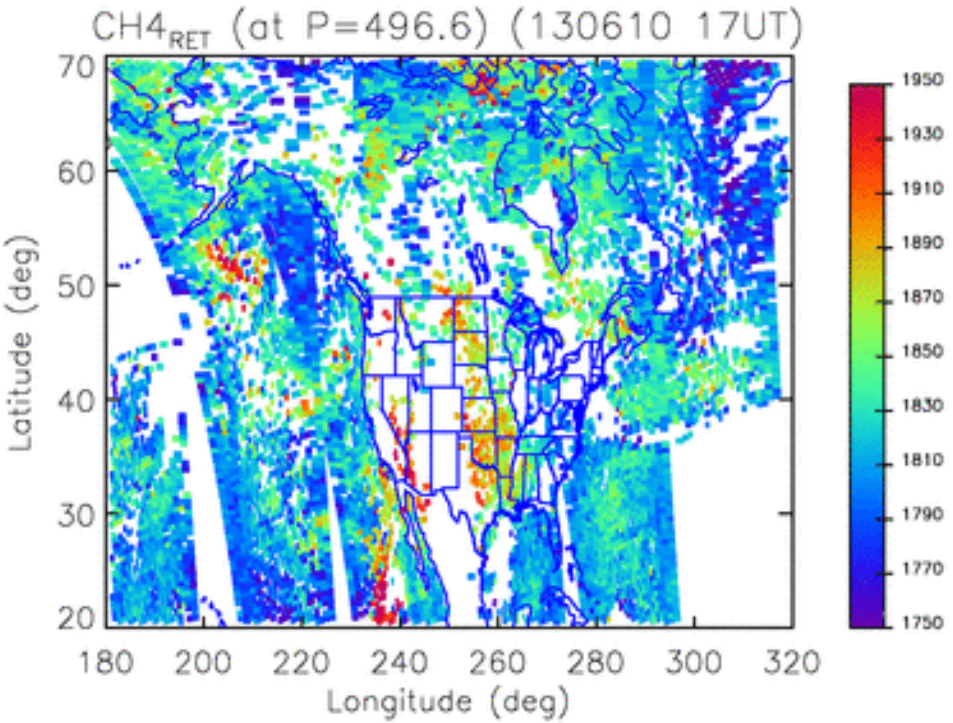
Operational Quality of NUCAPS QC

Night Time
AM orbit (~01h30)

NUCAPS has 17 threshold tests throughout retrieval process that inform final IR/MR QC flag

Day Time
PM orbit (~13h30)





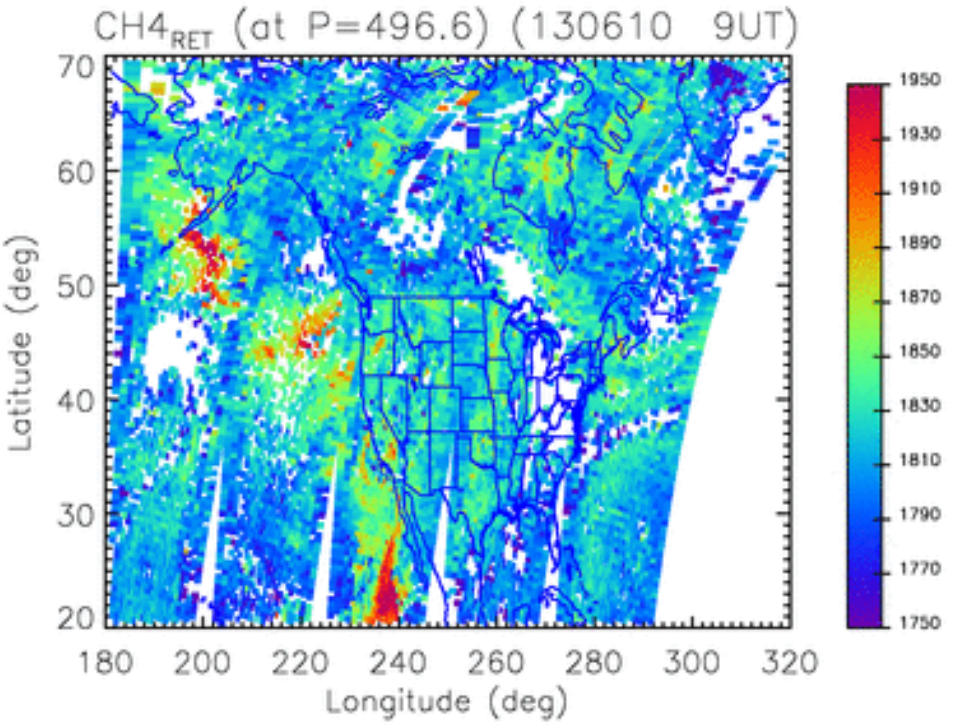
Time Continuity and consistency matters in Air Quality Monitoring Applications

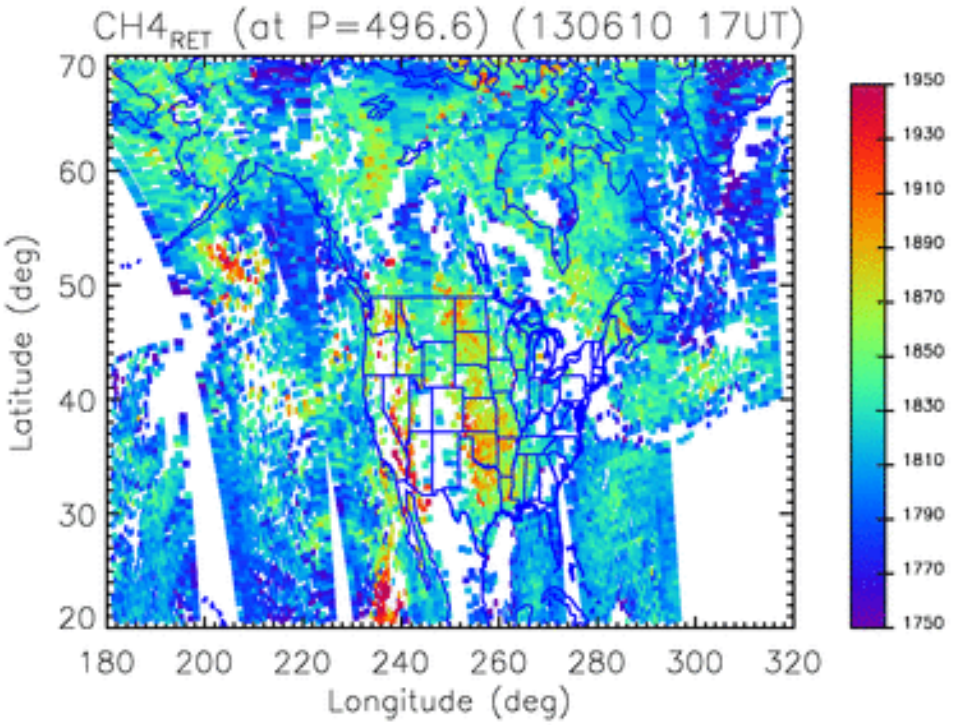
Can we improve NUCAPS QC? – Yes

Night Time
AM orbit (~01h30)

Retrieval yield is sensitive to small changes in QC thresholds

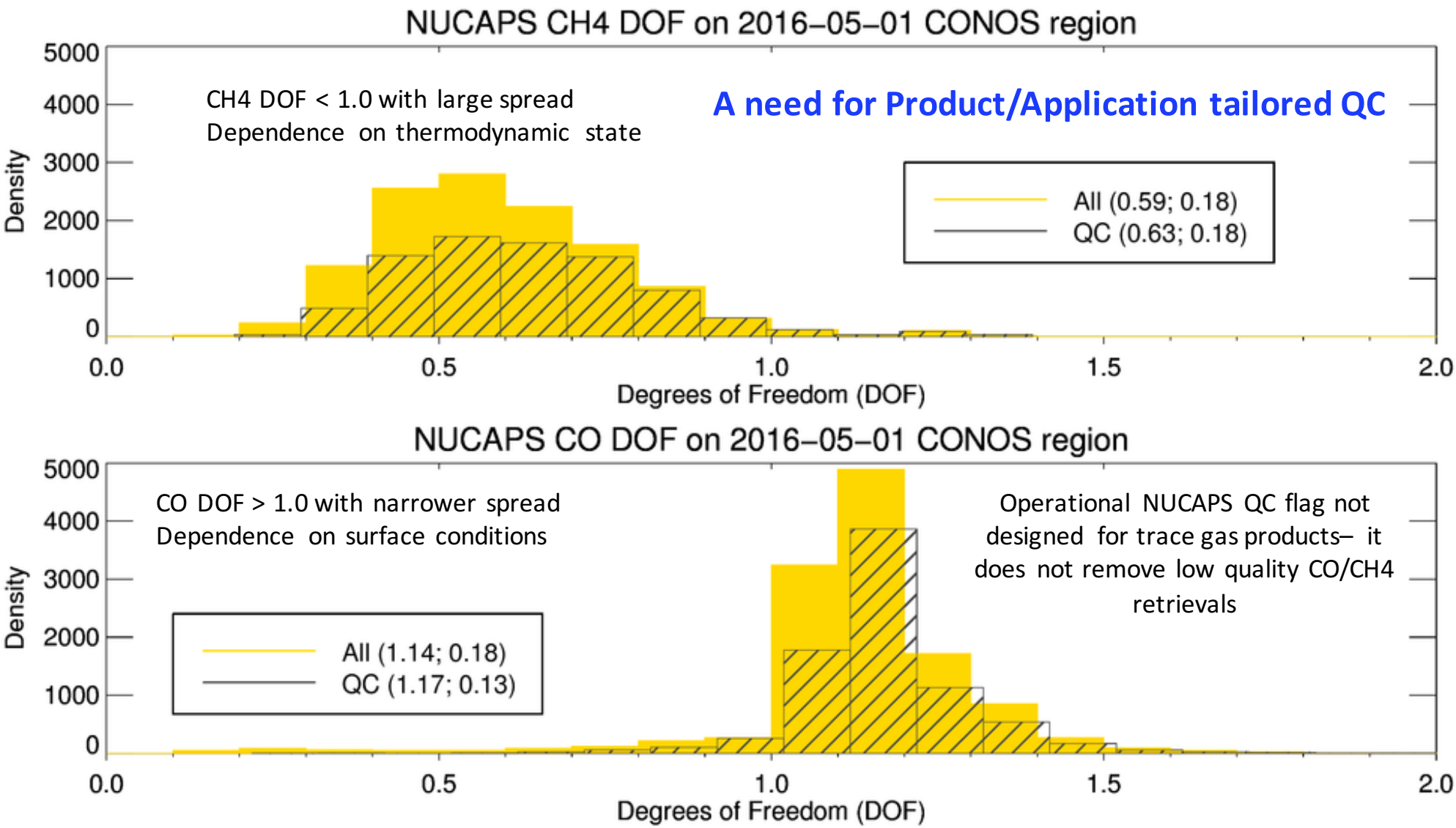
Day Time
PM orbit (~13h30)





~4% increase in retrieval yield

~12% increase in retrieval yield


NUCAPS CH4 DOF on 2016–05–01 CONOS region
CH4 DOF < 1.0 with large spread
Dependence on thermodynamic state
A need for Product/Application tailored QC
All (0.59; 0.18)
QC (0.63; 0.18)
Density
Degrees of Freedom (DOF)
NUCAPS CO DOF on 2016–05–01 CONOS region
CO DOF > 1.0 with narrower spread
Dependence on surface conditions
Operational NUCAPS QC flag not designed for trace gas products– it does not remove low quality CO/CH4 retrievals
All (1.14; 0.18)
QC (1.17; 0.13)
Density
Degrees of Freedom (DOF)

Moving Forward

Application Development

Introduce variance scaling as alternative metric of atmospheric structure

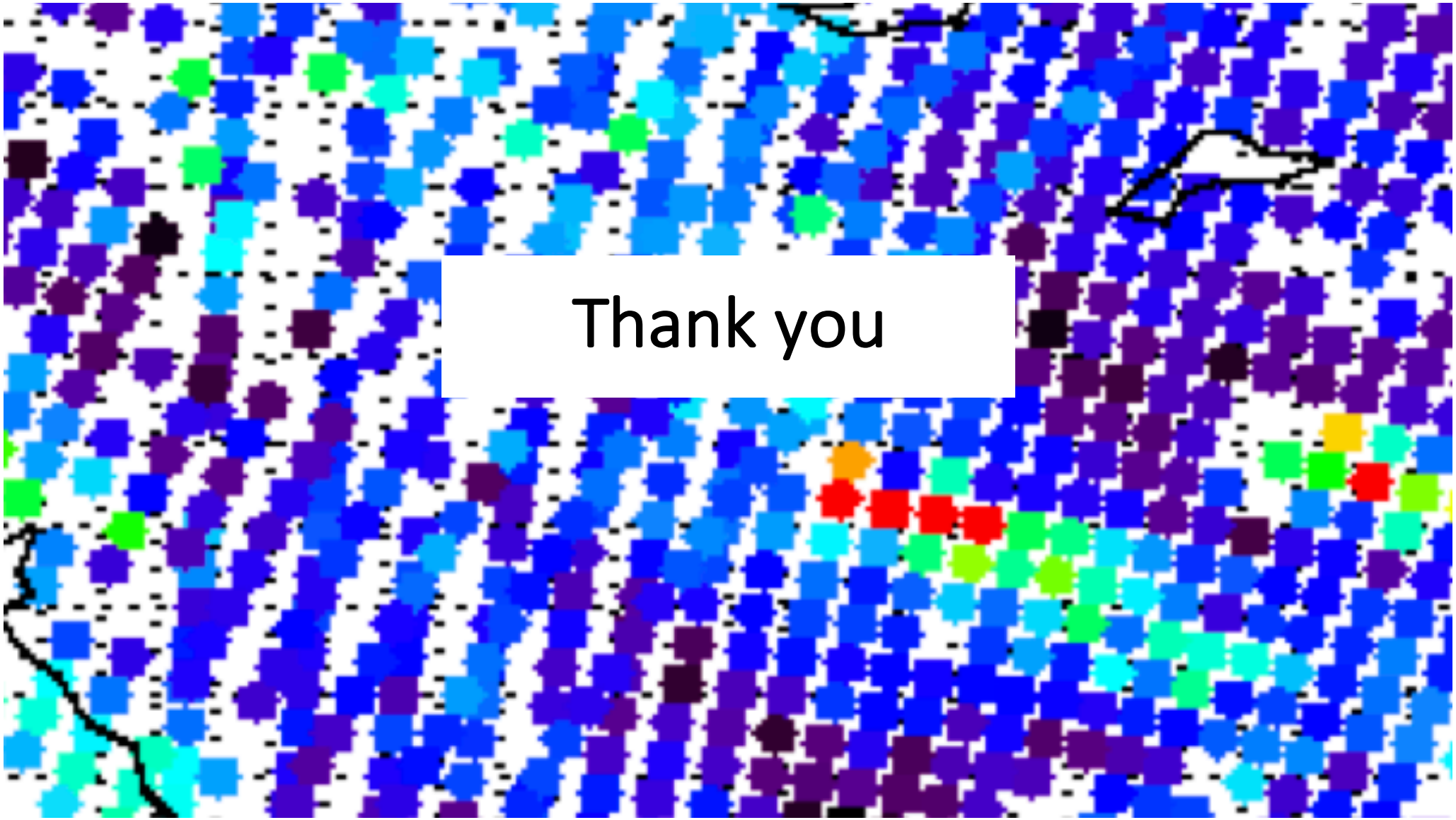
- It can handle data gaps (due to QC)
- Help inform the optimal spatial averaging requirements for NUCAPS trace gas products
- Is an application that is uniquely suited to retrieval products (high variance), not radiances (low variance),
- Provides a means with which to analyze atmospheric structure and processes at multiple space-time scales.

Algorithm Development – improve trace gas a priori, surface emissivity (indirect effect on CH4, direct on CO), channel lists, add multi-instrument capability (+IASI)

Product Development – Design Operational Auxiliary product format (reduced resolution AK + DOF + diagnostic information)

In Summary

- The NOAA Proving Ground and Risk Reduction (PGRR) Initiative allows Users and Developers to collaborate and more effectively work towards solutions – we are all learning in the process
- There is a user need to not only improve the retrieval quality, but also the data product design and tailor the type of information made available in the data product files
- Given that QC removes data, we need to understand how the systematic patterns in data sampling affect analyses and propagate into applications
- More generally, major sources of systematic uncertainty have to be characterized for trace gas products to have value in applications.
- Our efforts lead to products tailored to user needs AND applications tailored to satellite data


Thank you